Excited Hadron States and the Deconfinement Transition

Concluding Discussion

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Workshop* *)

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If we would hold a follow-up workshop in 2 years from now, which questions would we like to be answered?

- Which QCD model describes the hadron (meson, baryon) spectrum best? E.g.:
  - Constituent quark model
  - MIT bag model
  - Flux-tube model
  - Holographic dual models
  - Large N_c expansion

- Is there a “constituent gluon” model?
- If yes, how do we understand the large gluon mass?
  - Scale breaking by the trace anomaly?
  - Additional spontaneous scale invariance breaking?
  - Is the constituent gluon a flux tube excitation?

- What is the relation between the deconfinement transition and the chiral transition?
  - Is it a well defined question?
  - Are they at the “same” temperature?
  - Do they drive each other?

- Where (at what T) and why does the hadron resonance gas model fail?
  - Do unknown hadron states (hybrids, tetraquarks, glueballs) contribute significantly in the range of validity?
  - If yes, which ones?

- What are the requirements for a valid description of the hadronic break-up of the quark-gluon plasma?
  - How must viscous hydrodynamics be matched to a kinetic description of the hadron gas?
  - What are the minimal matching conditions?
  - In which temperature range can the matching be performed?
  - What are the most sensitive experimental tests?

- Where does the hot glue in the quark-gluon plasma go?
  - Does it fragment into quark pairs?
  - Does it initially end up in gluonic excitations?
  - Is it possible to measure the average amount of excited glue in hadrons for a given mass or temperature on the lattice?

- Can finite temperature lattice calculations determine average aspects of the hadron spectrum?
  - Analogy with the Monte-Carlo shell model of Koonin, Ormand, Dean, Langanke, et al, who used MC methods to obtain level densities and Gamov-Teller strengths in the shell model for complex nuclei (e.g. *Annu. Rev. Nucl. Part. Phys.* **47**, 463).

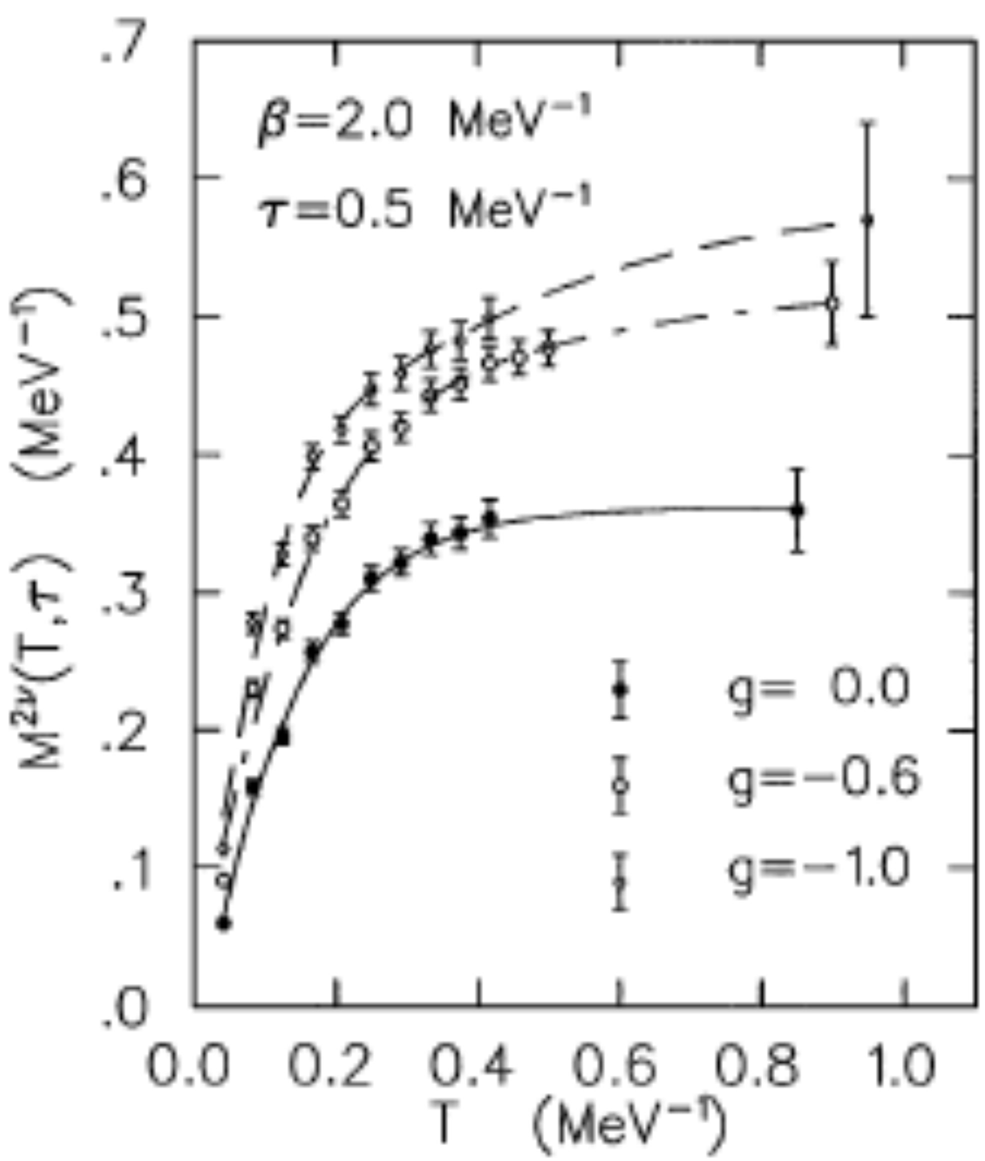
$$M^{2\nu} = \sum_m \frac{\langle 0_f^+|\mathrm{G}|1_m^+\rangle \cdot \langle 1_m^+|\mathrm{G}|0_i^+\rangle}{E_m - (E_i^0 + E_f^0)/2}.$$

Laplace transform:

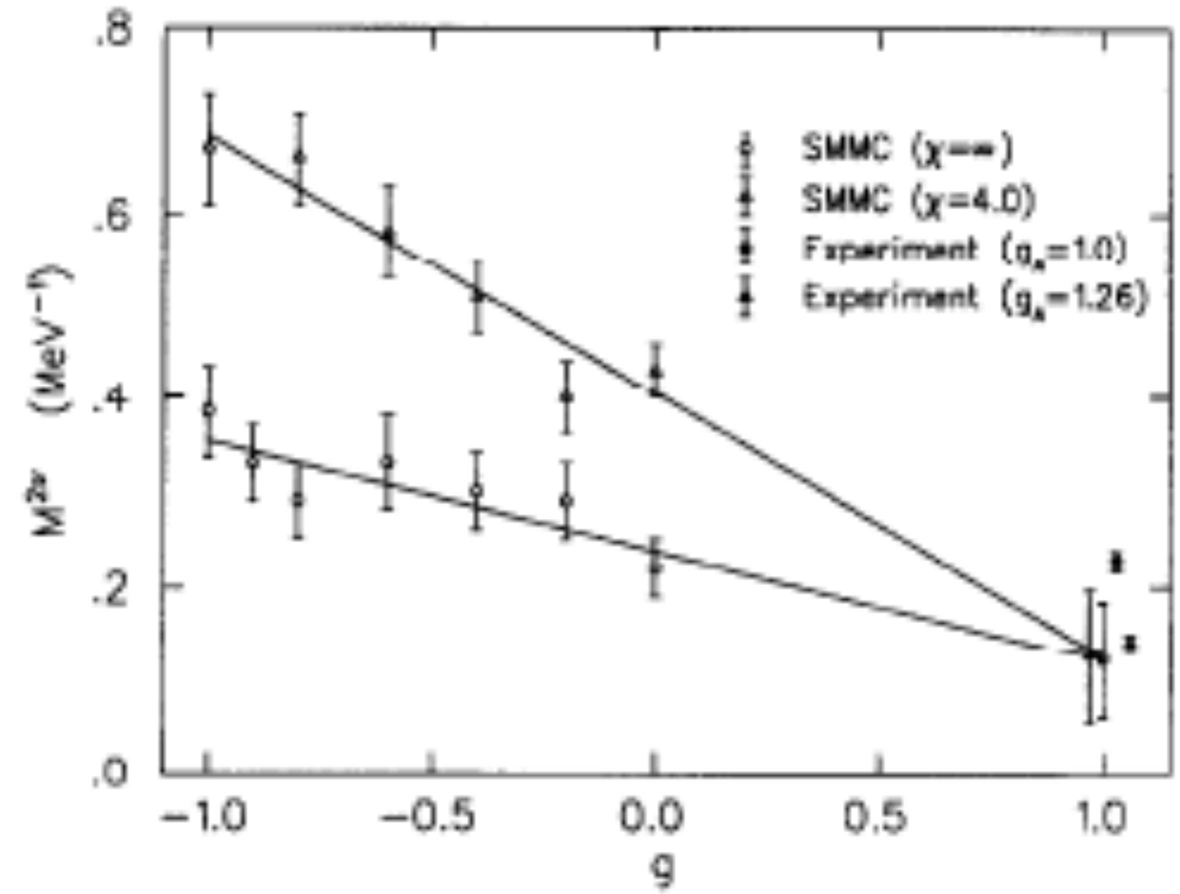
$$M^{2\nu}(T,\tau) = \frac{\eta(T,\tau)M_c^*}{\phi(\tau,0)},$$

$$\phi(\tau,\tau') = \frac{\mathrm{Tr}[e^{-(\beta-\tau-\tau')H}\mathrm{G}^\dagger \cdot \mathrm{G}^\dagger e^{-\tau H}\mathrm{G}e^{-\tau' H} \cdot \mathrm{G}]}{\mathrm{Tr}[e^{-\beta H}]}$$

$$\eta(T,\tau) = \int_0^T d\tau' \, \phi(\tau,\tau')e^{-\tau' Q/2}$$



2ν matrix element for ^{76}Ge



- Do we need a complementary “hadron data” effort supported by the nuclear (hadron) physics community to make excited hadron data that are ignored by the PDG widely available?
  - What form would this take, if we wanted to ensure convenience of use and adequate quality control, without duplicating aspects of the PDG effort?
  - Could this be part of the future role of EBAC (PAC) ?
  - How quickly could this be done?